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Li et al.

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(54) **POLARIZED ELECTROMAGNETIC RELAY**

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H01H 50/56 (2006.01)

(52) **U.S. Cl.**
CPC ***H01H 51/22*** (2013.01); ***H01H 51/2209*** (2013.01); *H01H 50/56* (2013.01)

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USPC 335/85
See application file for complete search history.

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(57) **ABSTRACT**

A polarized electromagnetic relay including an electromagnet; a pair of magnetic pole pieces driven by the electromagnet; a permanent magnet attached to the magnetic pole pieces; a contact section including a first fixed contact member with a normally open fixed contact, a first movable contact member with a normally open movable contact, a second fixed contact member with a normally closed fixed contact, and a second movable contact member with a normally closed movable contact; and a transmission member to which the magnetic pole pieces is attached. In accordance with a rectilinear movement of the magnetic pole pieces in parallel to a coil center axis, the transmission member rectilinearly moves in parallel to the center axis and thereby causes the normally open and closed movable contacts to perform an opening or closing operation in a mutually interlocked manner.

8 Claims, 15 Drawing Sheets

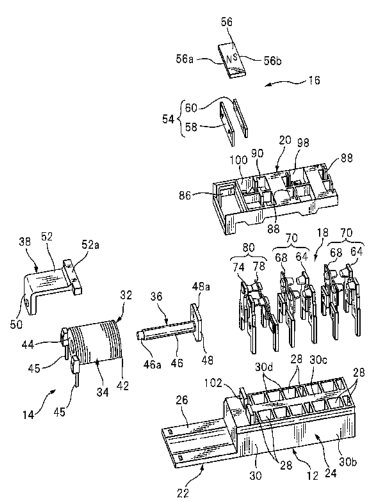

FIG. 1

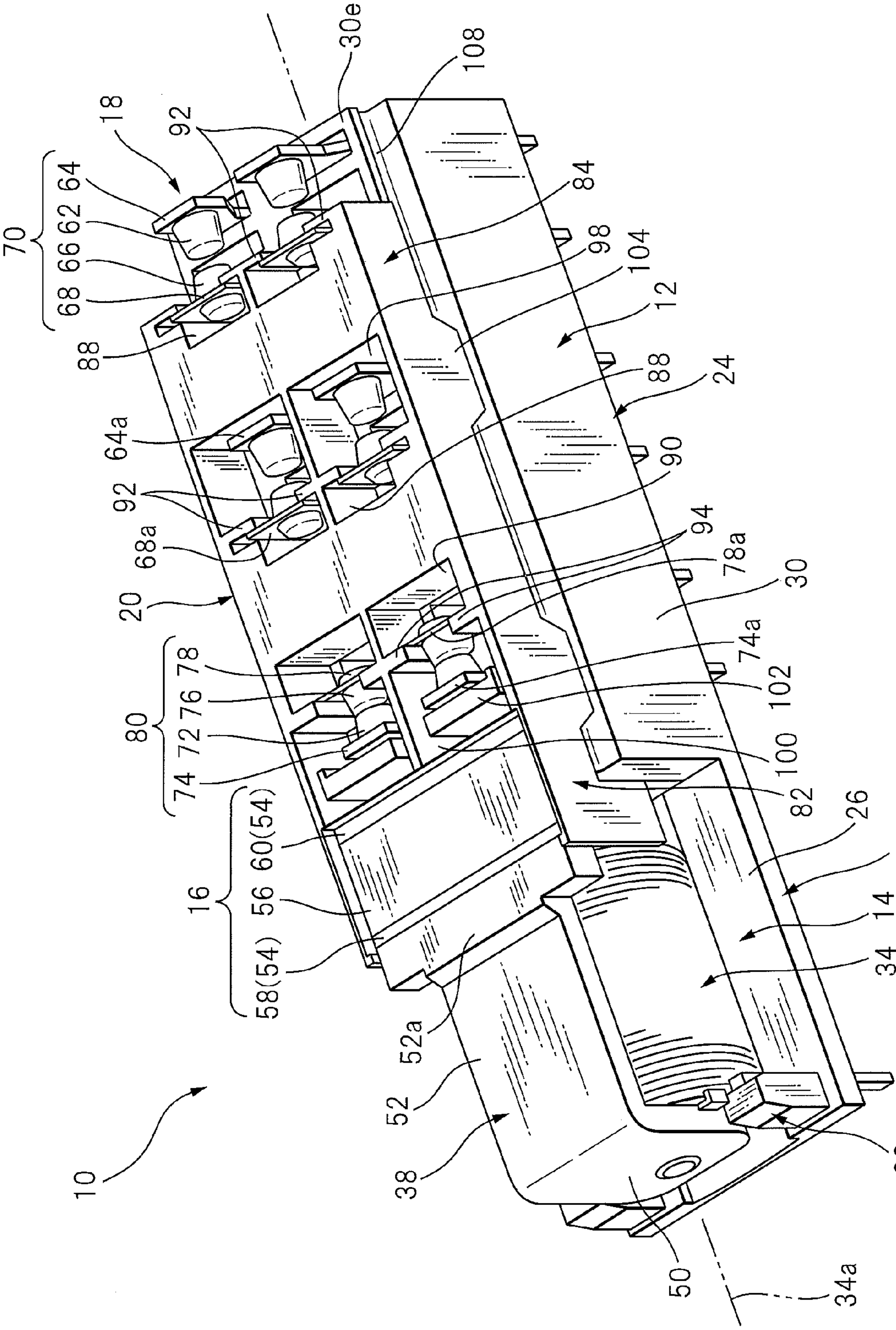
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FIG. 2

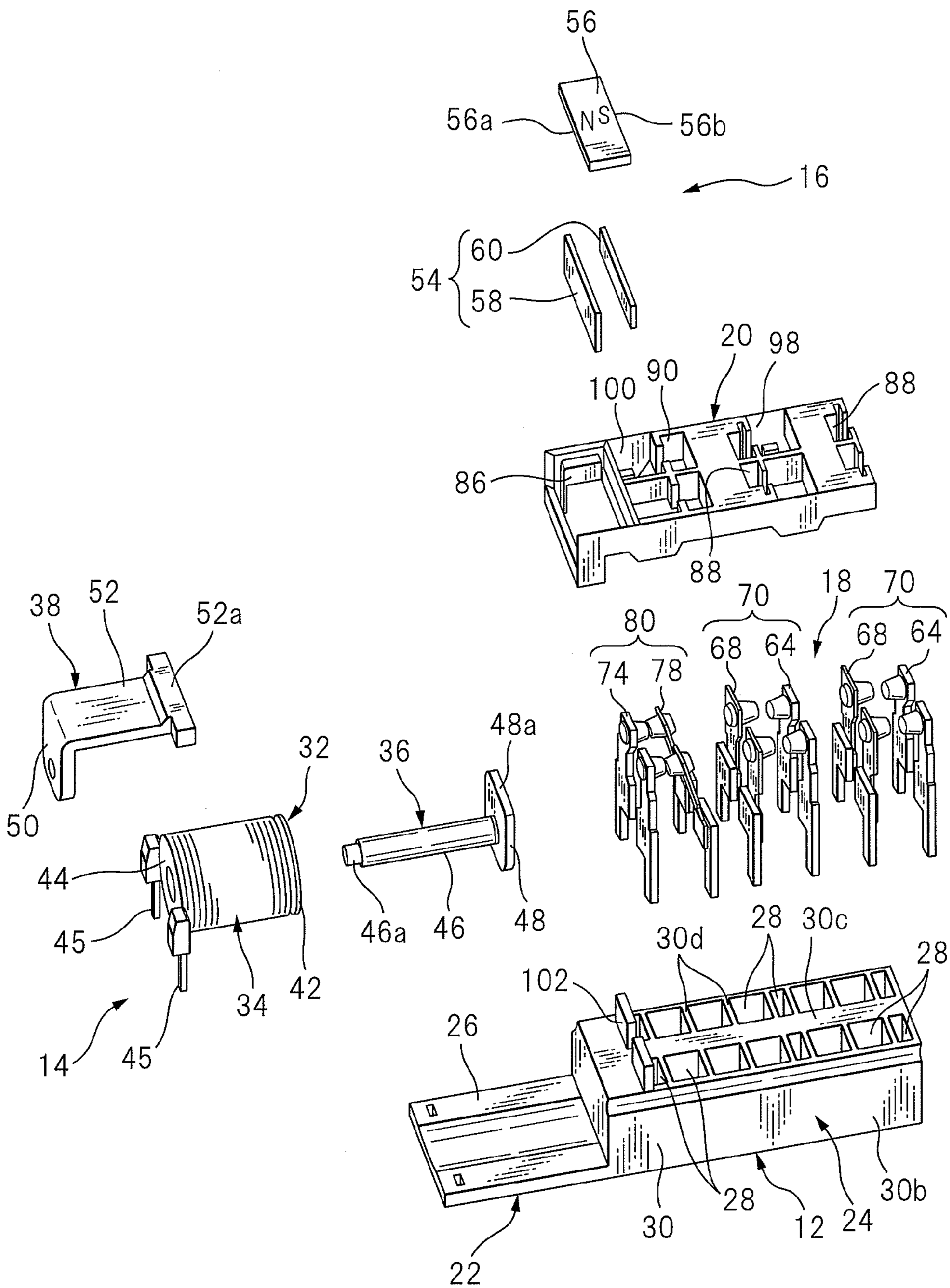

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FIG. 3

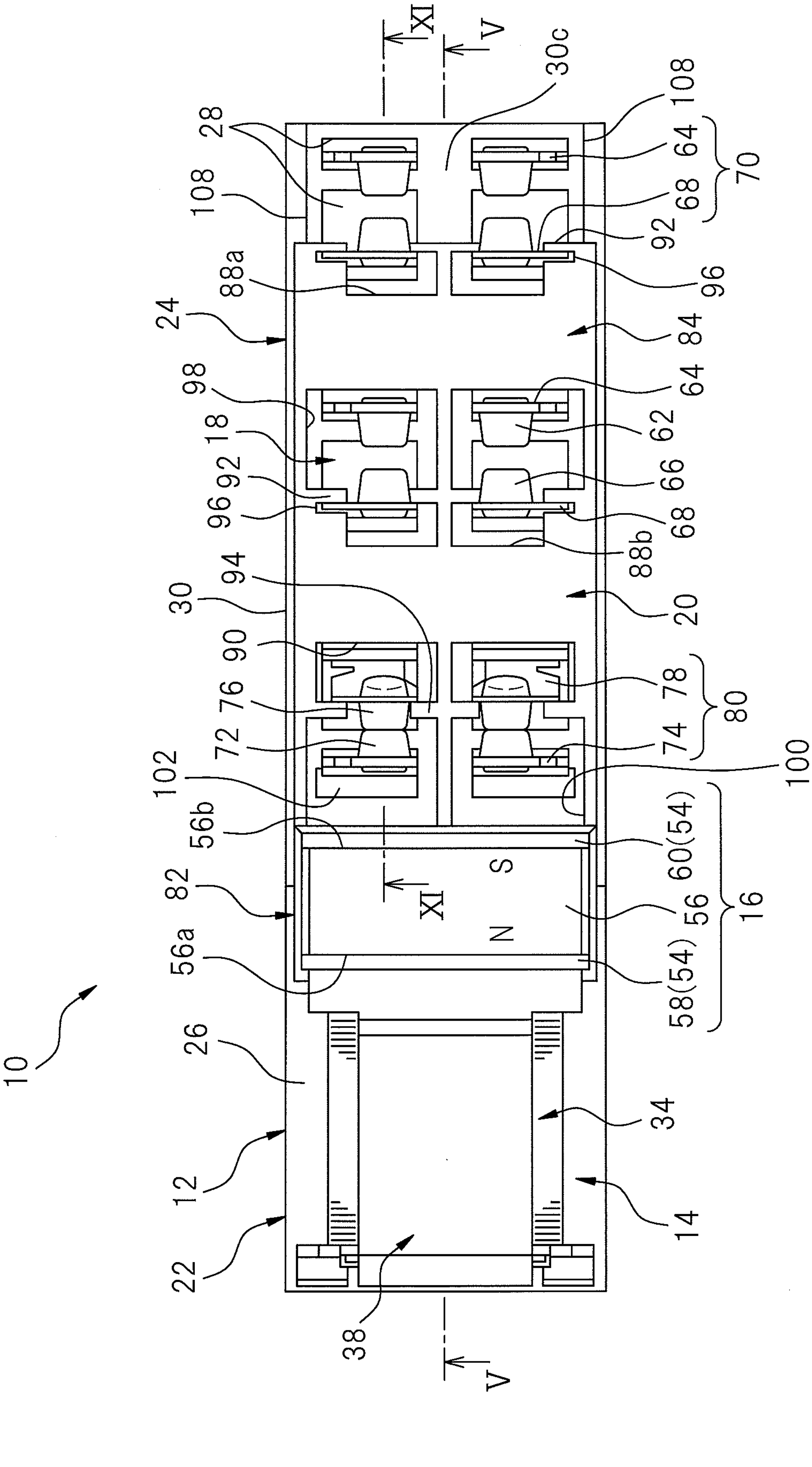

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FIG. 4

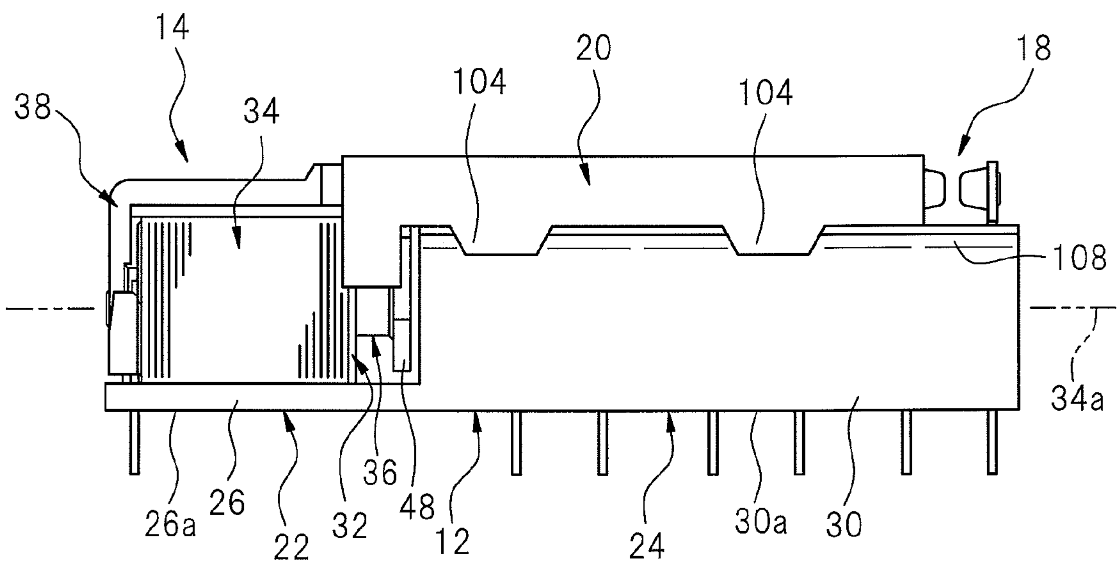

FIG. 5

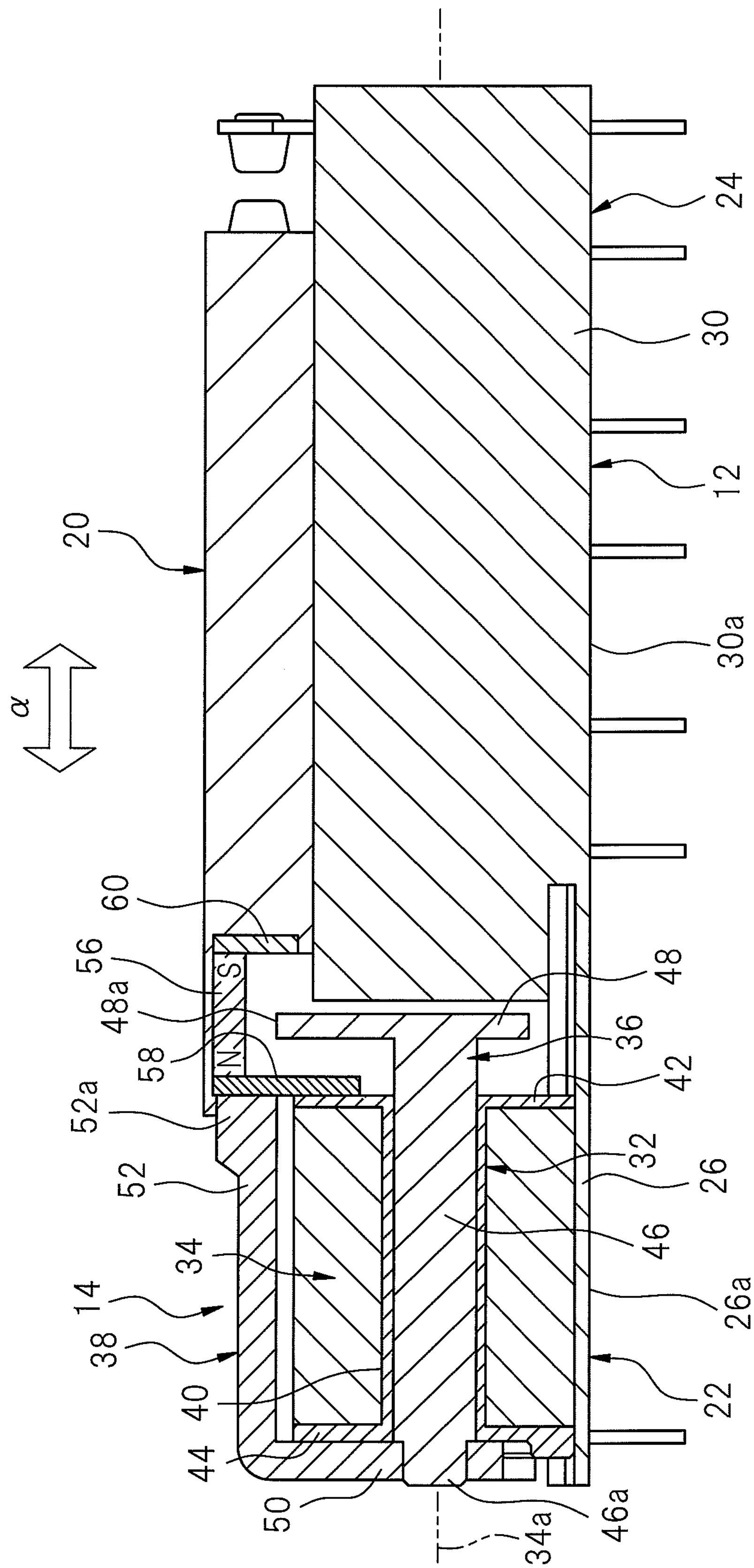

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FIG. 6

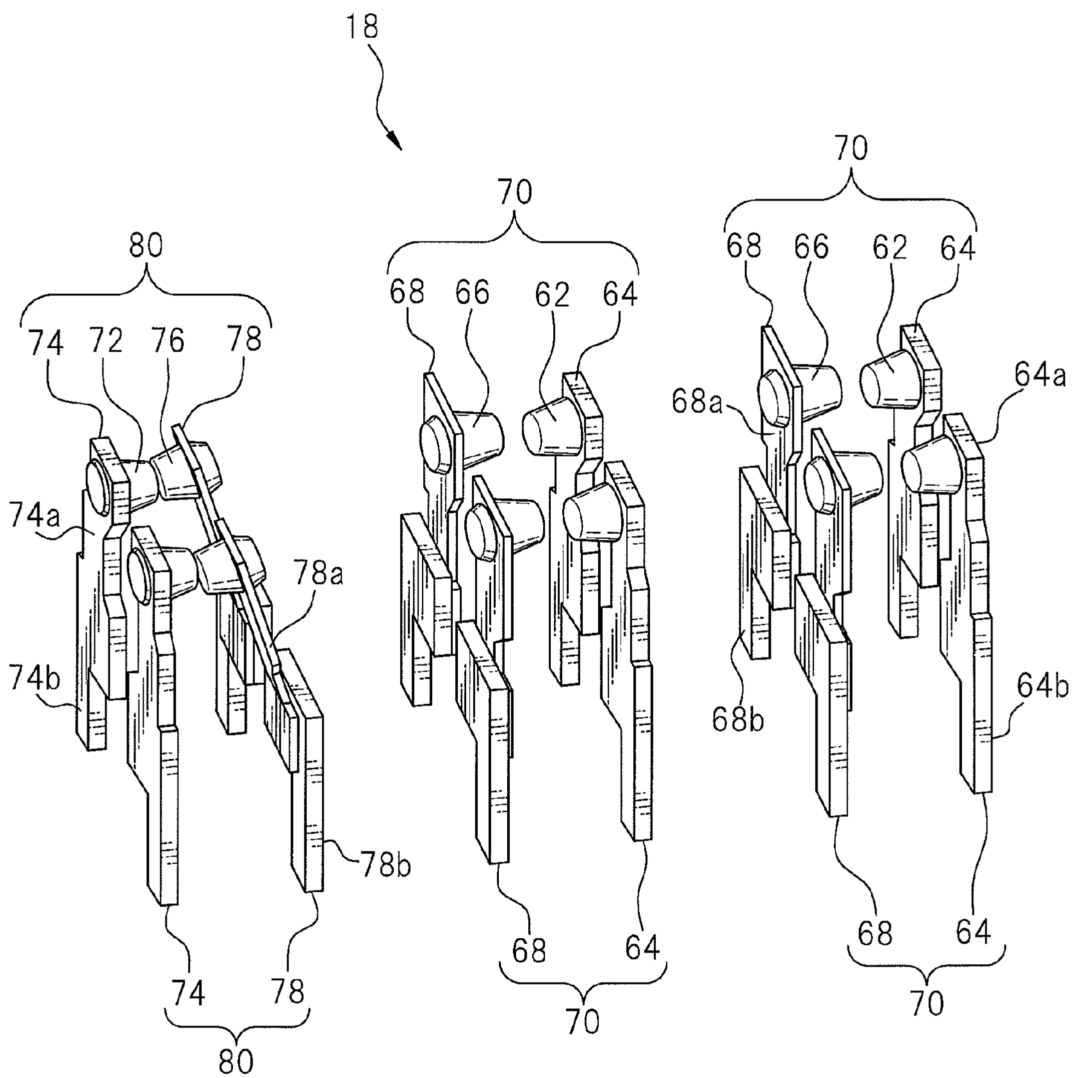
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FIG. 7

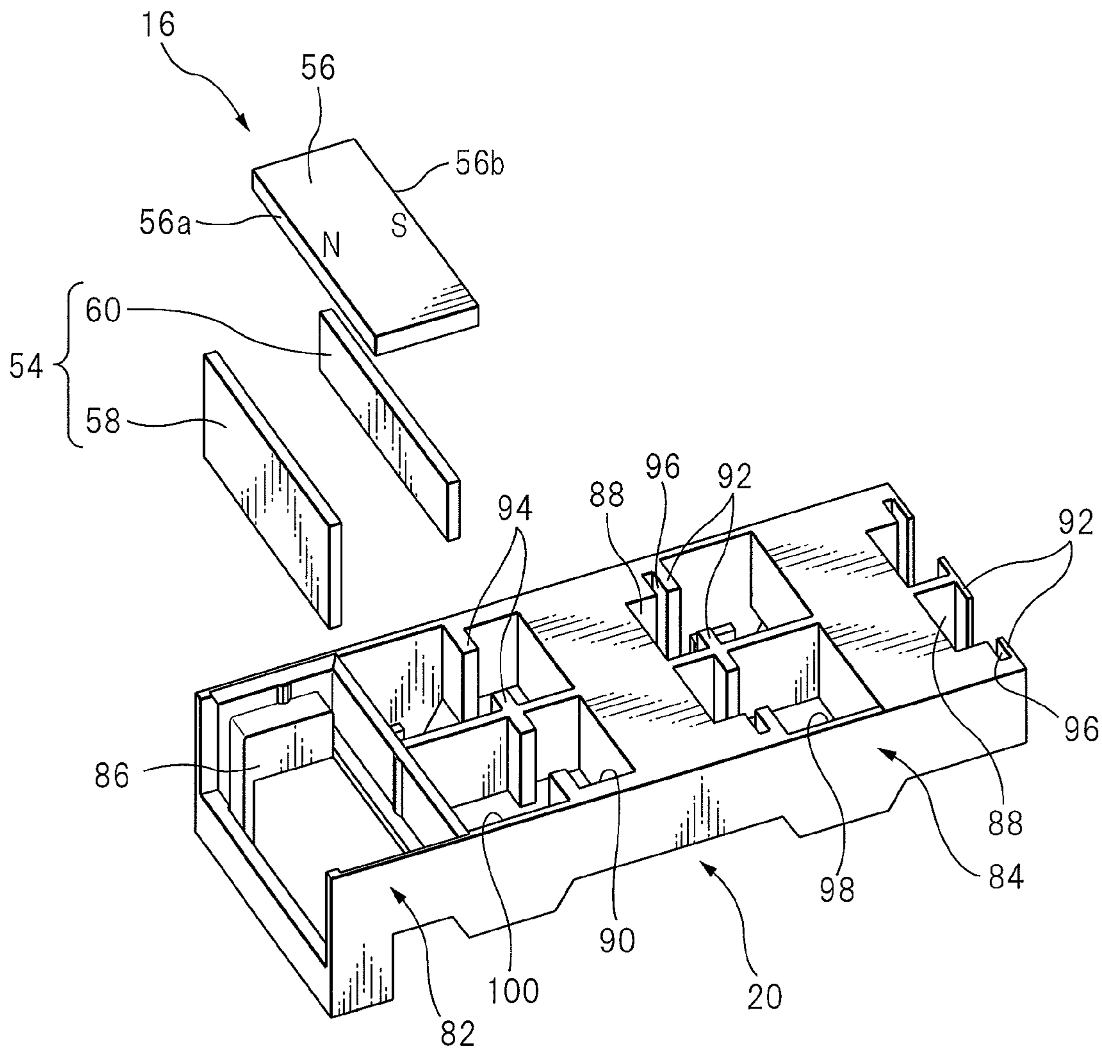

FIG. 8

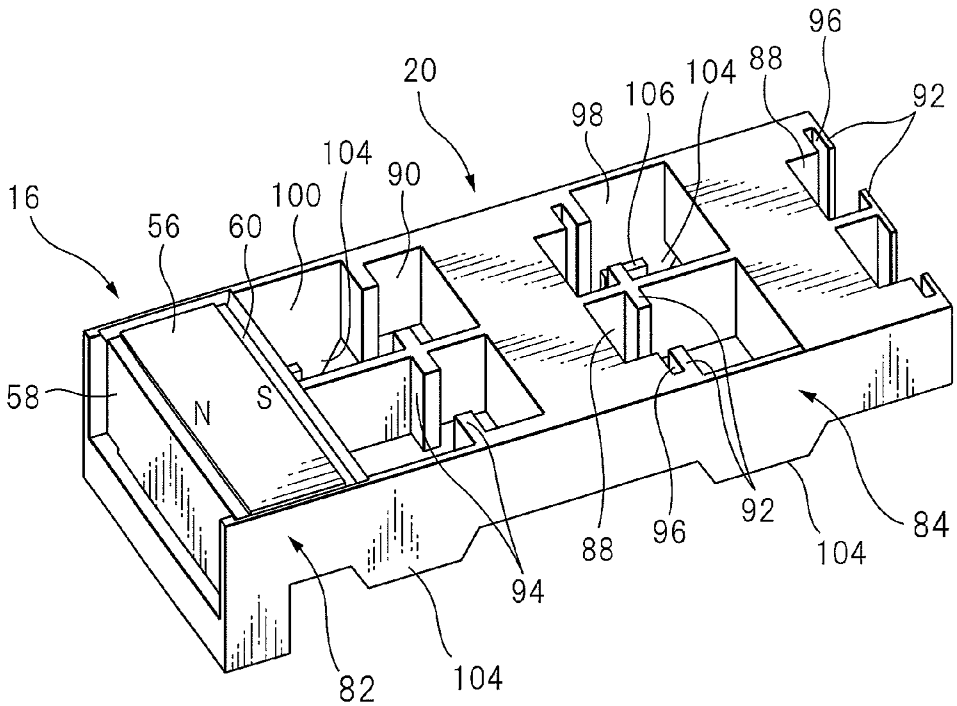
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FIG. 9

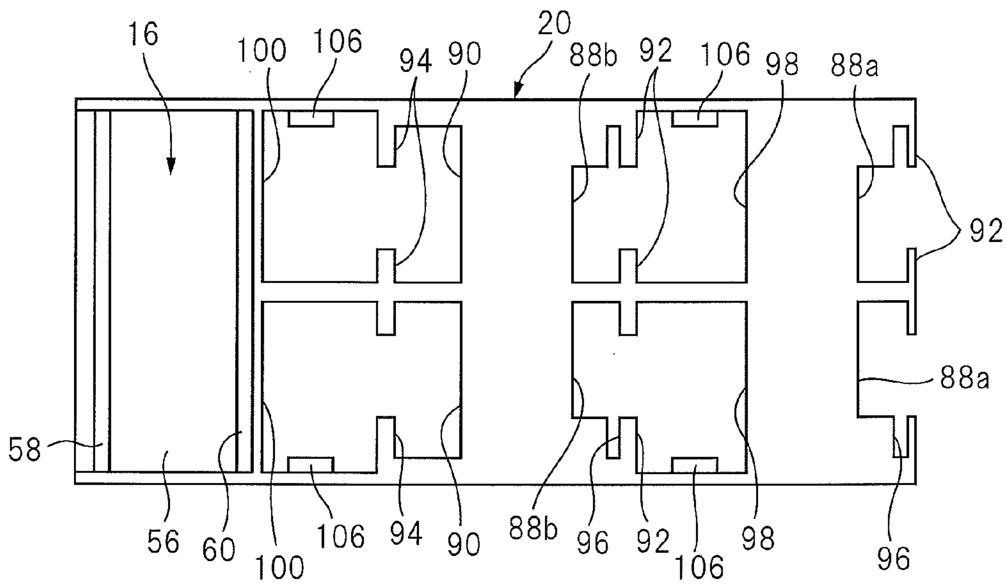
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FIG. 10

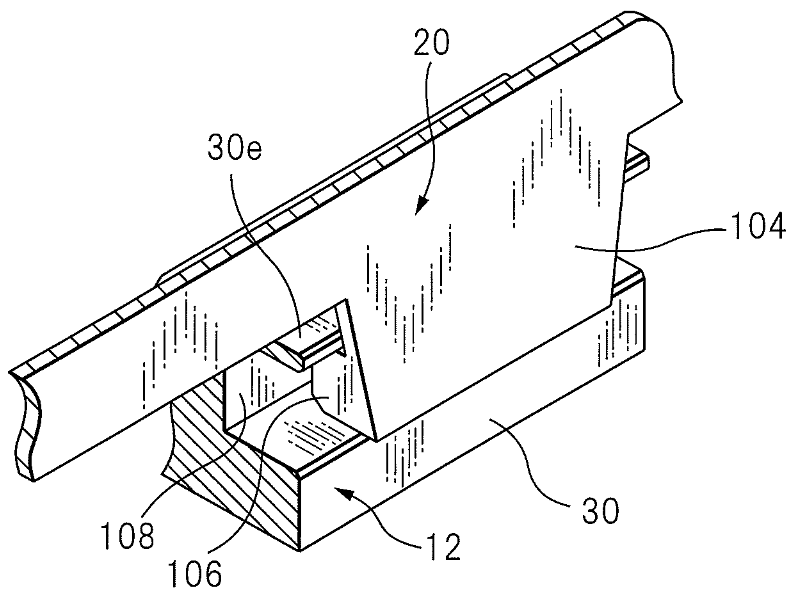


FIG. 11A

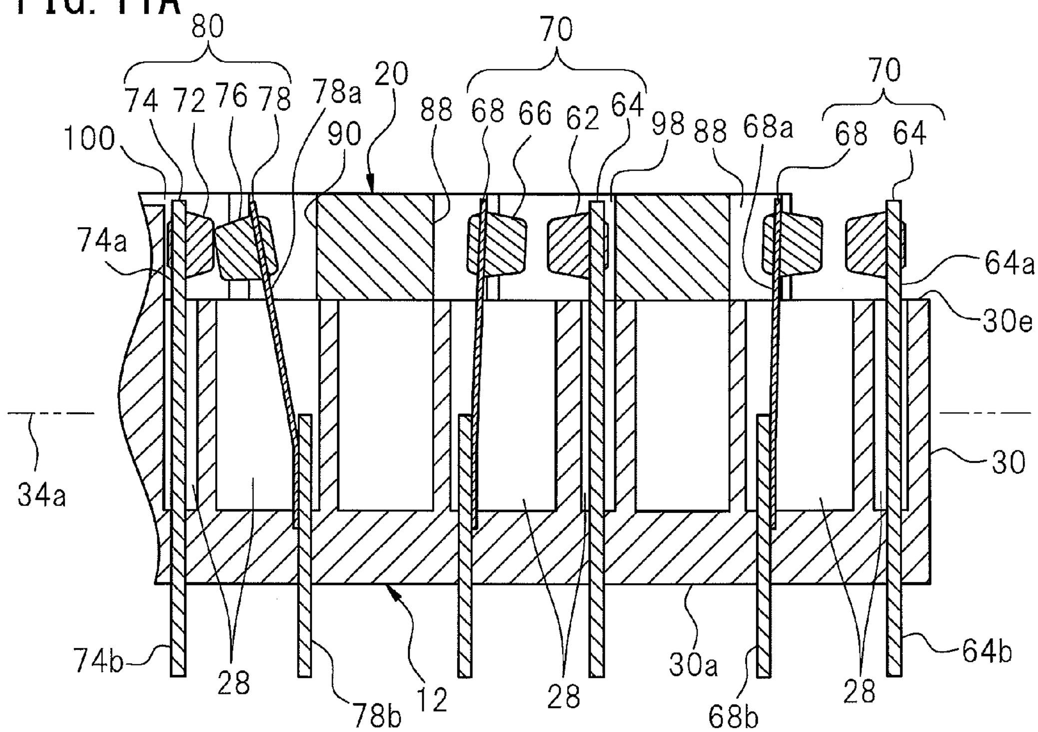


FIG. 11B

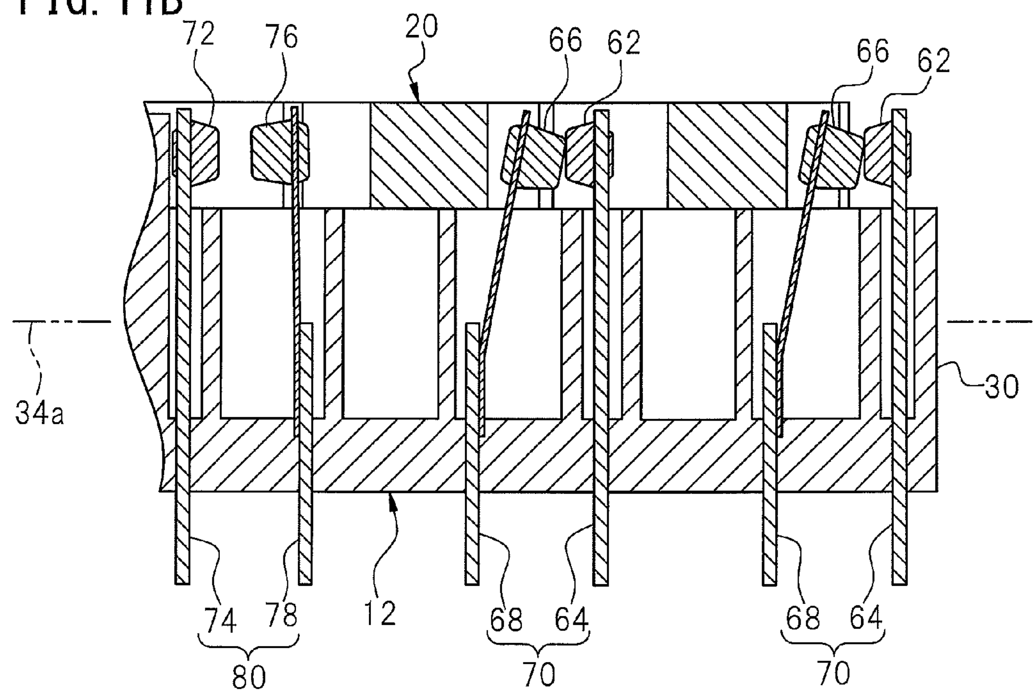


FIG. 12A

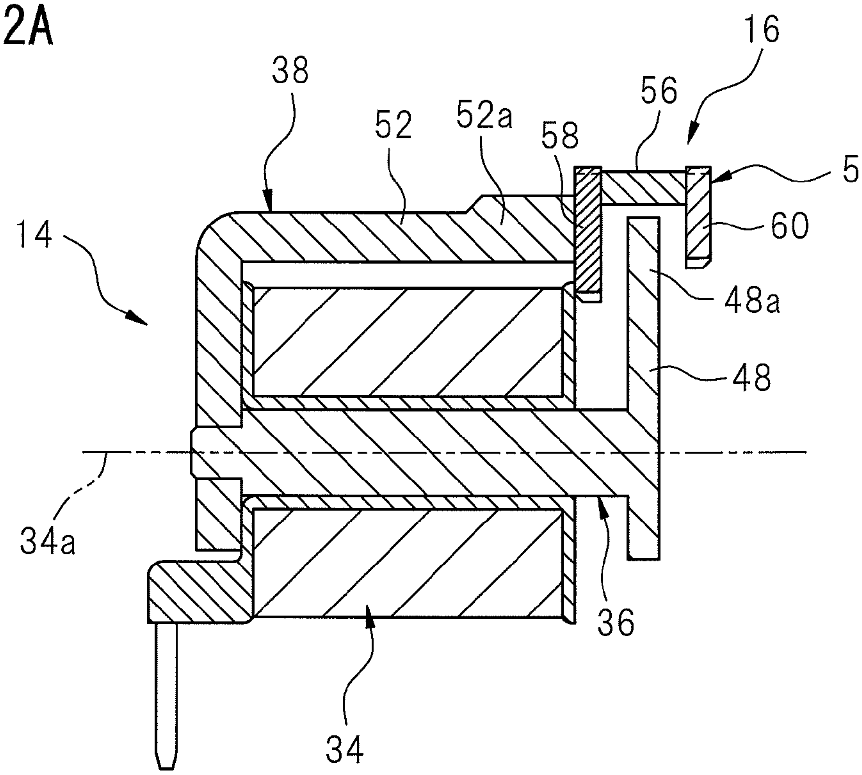


FIG. 12B

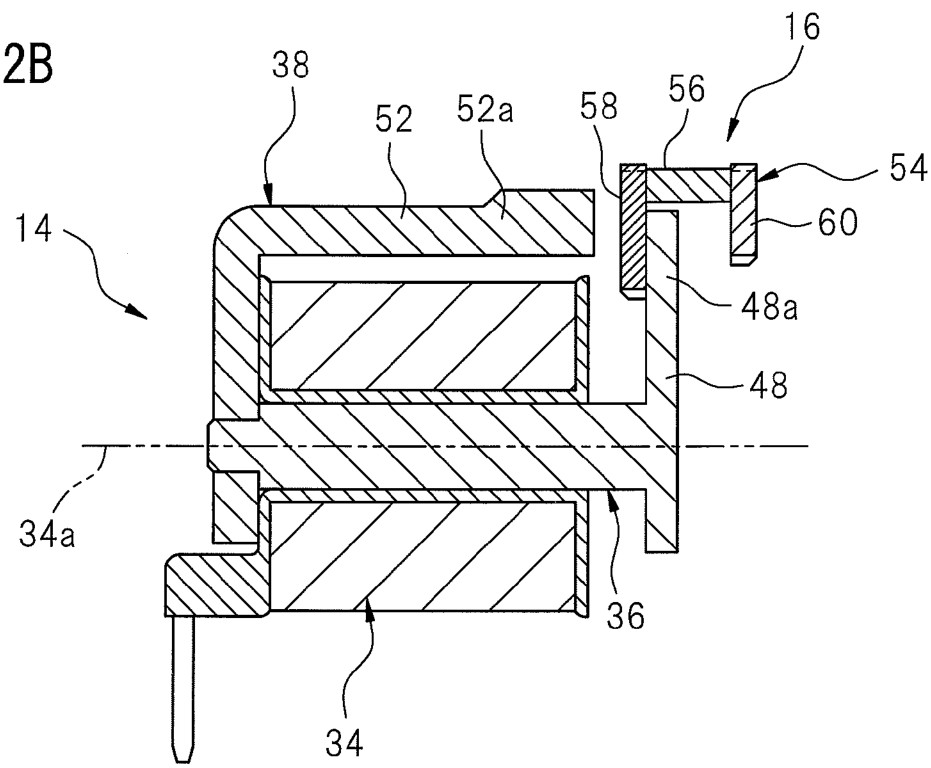


FIG. 13

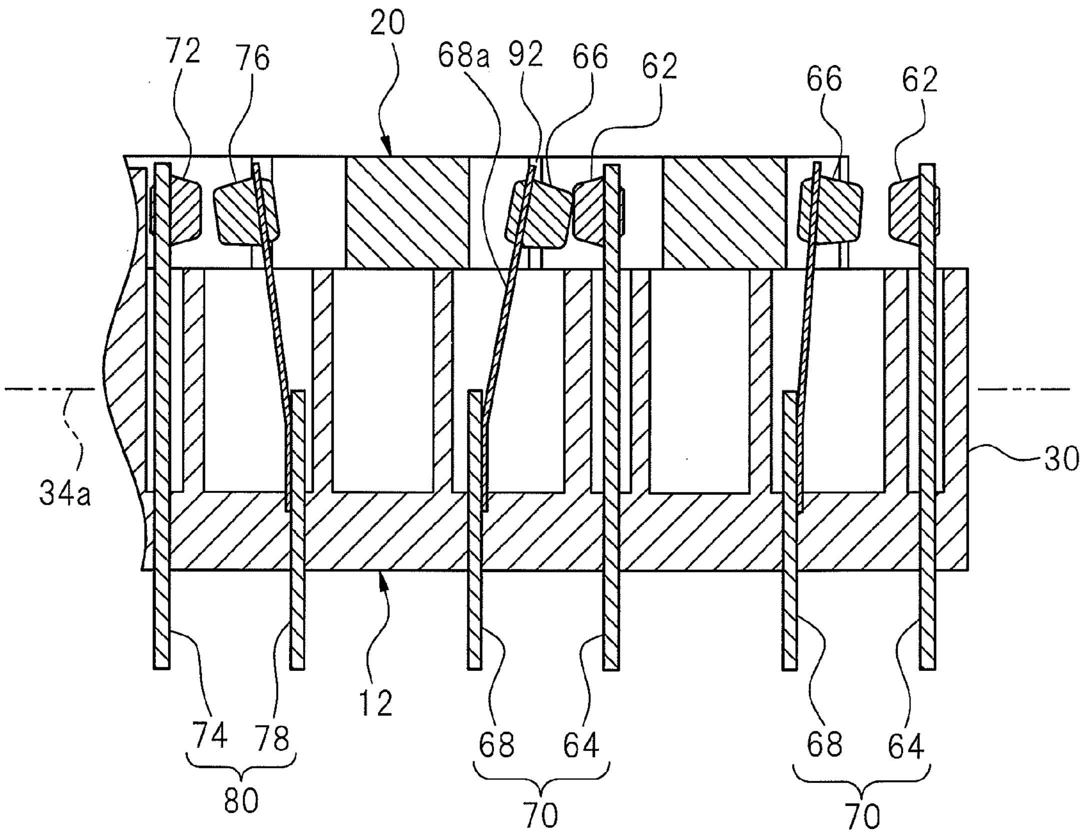


FIG. 14

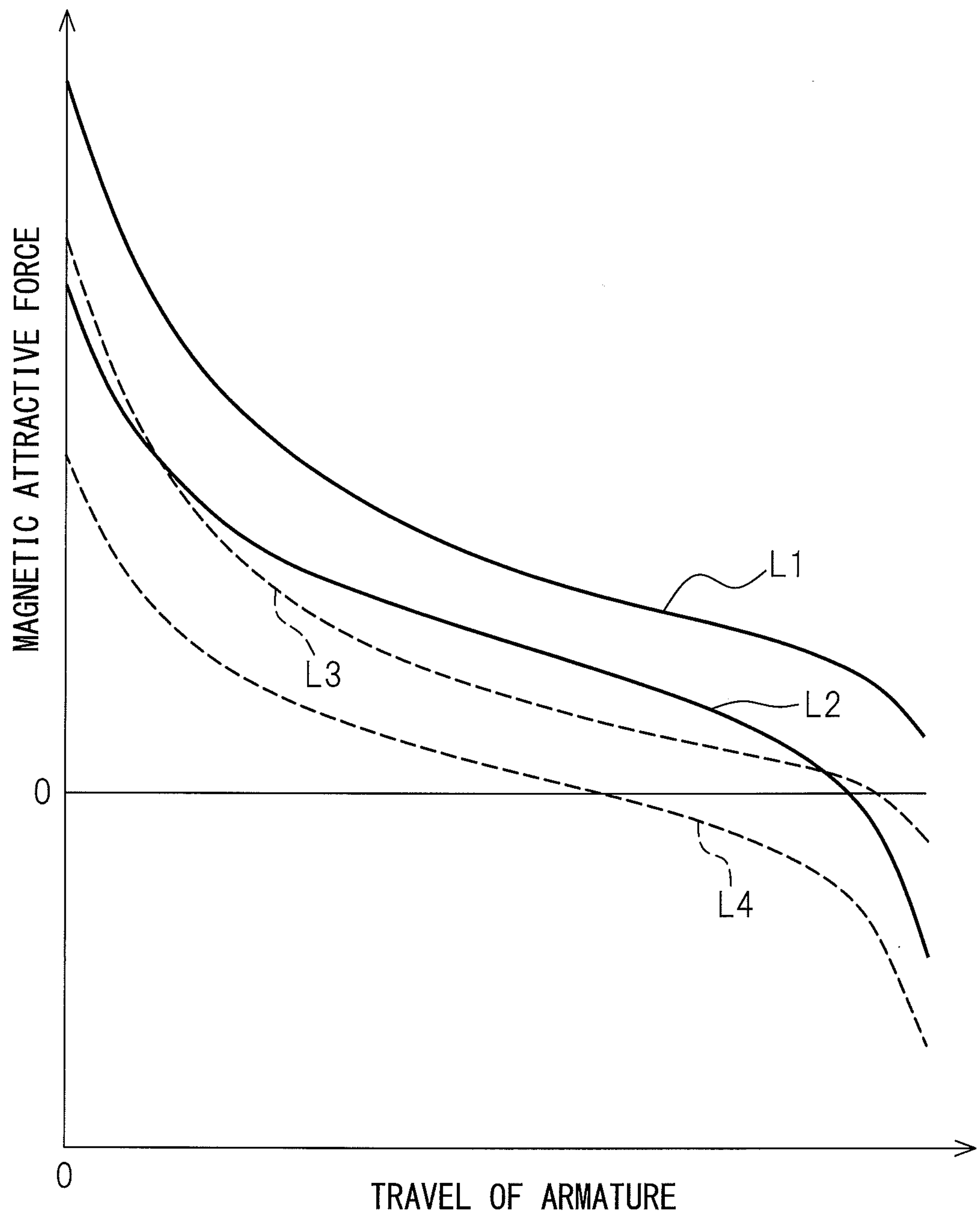


FIG. 15

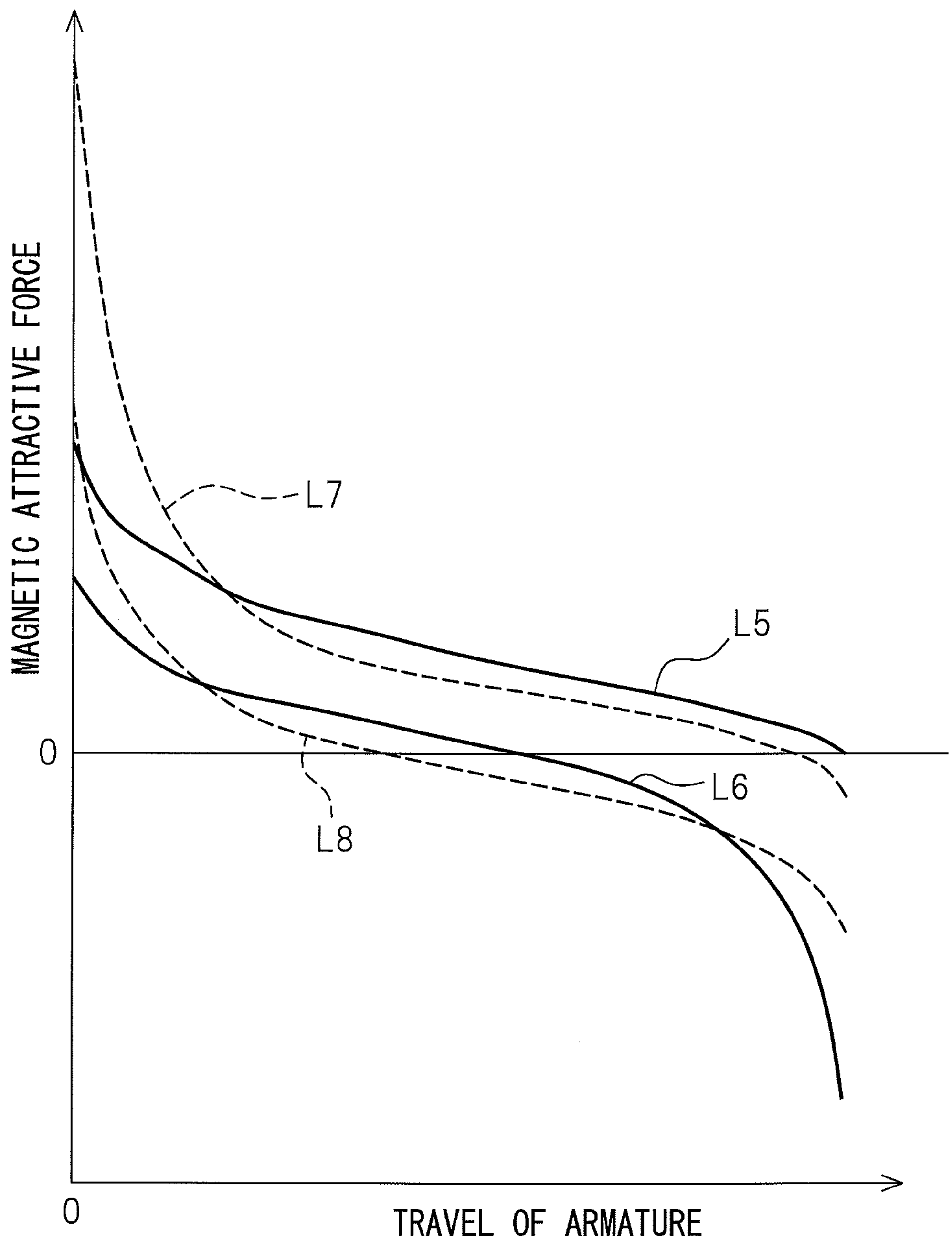


FIG. 16A

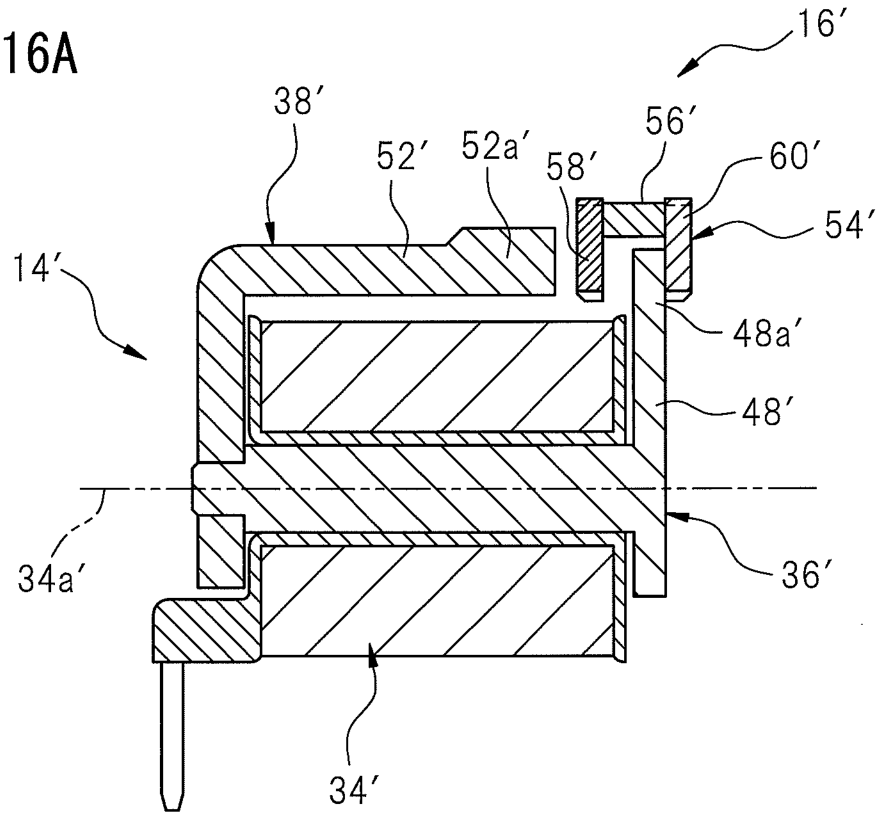
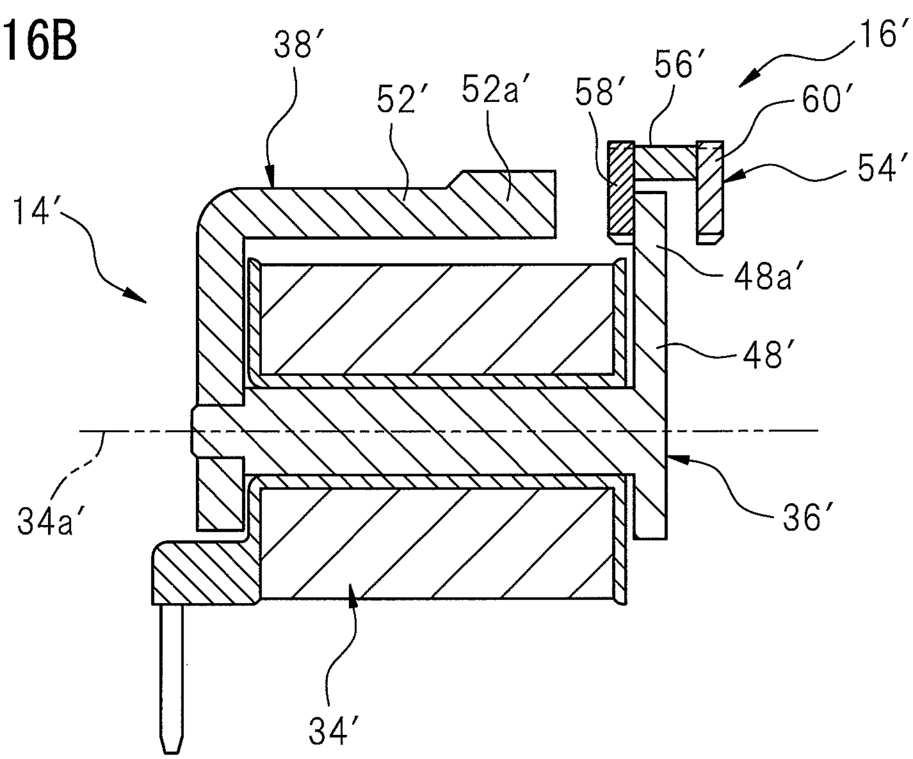


FIG. 16B



POLARIZED ELECTROMAGNETIC RELAY

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the benefit of priority of the prior Japanese Application No. 2012-082359, filed Mar. 30, 2012, and No. 2013-023449, filed Feb. 8, 2013, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a polarized electromagnetic relay.

2. Description of the Related Art

An electromagnetic relay including at least one pair of normally open contacts and at least one pair of normally closed contacts, in which the pair of normally open contacts and the pair of normally closed contacts perform an opening or closing operation in a manner mechanically interlocked with each other in accordance with the movement of an armature, and the individual pair of contacts are arranged insulated from one another, has been known. This type of electromagnetic relay can be used as, e.g., a relay with forcibly guided contacts (also referred to as a safety relay) in which, the failure of any normally open contact to open (e.g., due to welding) has the effect that none of the normally closed contacts close even when the relay is not energized. A circuit incorporating such a safety relay can detect the welding of the pair of normally open contacts and can maintain a power shutoff condition.

An electromagnetic relay having a forcibly guided contact configuration is described in, e.g., Japanese Unexamined Patent Publication (Kokai) No. 6-176676 (JP6-176676A). The electromagnetic relay described in JP6-176676A includes an actuating member operating against the biasing force of a return spring in accordance with the swinging motion of an armature moving like a hinge, and is constructed so that a pair of normally open contacts and a pair of normally closed contacts perform an opening or closing operation in a manner mechanically interlocked with each other in accordance with the movement of the actuating member and the pair of normally open contacts and the pair of normally closed contacts can never be simultaneously in closed position. The actuating member moves in a direction perpendicular to the center axis of a coil of an electromagnet used to operate the armature. The electromagnet is placed so that the center axis of the coil is oriented perpendicularly to the bottom face of the relay.

On the other hand, in a polarized electromagnetic relay including the combination of an electromagnet and a permanent magnet, it is known to provide a low-profile configuration in which the electromagnet is placed so that the center axis of a coil is oriented in parallel to the bottom face of the relay, and in which an armature with the permanent magnet attached thereto is reciprocated in a direction parallel to the center axis of the coil (refer to, e.g., Japanese Unexamined Patent Publication (Kokai) No. 2008-210776 (JP2008-210776A)). The polarized electromagnetic relay described in JP2008-210776A has a so-called transfer-type contact configuration, comprising a single movable contact spring member that supports a movable make (or normally open) contact and a movable break (or normally closed) contact in a back-to-back configuration, a first fixed contact terminal member that supports a fixed make (or normally open) contact capable of contacting and separating from the movable make contact, and a second fixed contact terminal member that supports a fixed break (or normally closed) contact capable of contacting and separating from the movable break contact.

SUMMARY OF THE INVENTION

One aspect of the present invention provides a polarized electromagnetic relay comprising an electromagnet including a coil; a pair of magnetic pole pieces driven by the electromagnet; a permanent magnet attached to the pair of magnetic pole pieces; a contact section including a first fixed contact member provided with a normally open fixed contact, a first movable contact member provided with a normally open movable contact capable of contacting and separating from the normally open fixed contact, a second fixed contact member provided with a normally closed fixed contact, and a second movable contact member proved with a normally closed movable contact capable of contacting and separating from the normally closed fixed contact; and a transmission member to which the pair of magnetic pole pieces is attached, the transmission member capable of transmitting a movement of the pair of magnetic pole pieces to the first movable contact member and the second movable contact member so as to cause the normally open movable contact and the normally closed movable contact to perform an opening or closing operation; wherein the pair of magnetic pole pieces holds therebetween the permanent magnet in a magnetization direction of the permanent magnet and is disposed to orient the magnetization direction in parallel with a center axis of the coil, the pair of magnetic pole pieces being rectilinearly movable together with the permanent magnet in an integrated manner in a direction parallel to the center axis; and wherein, in accordance with a rectilinear movement of the pair of magnetic pole pieces in the direction parallel to the center axis, the transmission member rectilinearly moves in the direction parallel to the center axis and thereby causes the normally open movable contact and the normally closed movable contact to perform the opening or closing operation in a mutually interlocked manner.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view depicting a polarized electromagnetic relay according to one embodiment;

FIG. **2** is an exploded perspective view depicting the polarized electromagnetic relay;

FIG. **3** is a plan view depicting the polarized electromagnetic relay;

FIG. **4** is a front view depicting the polarized electromagnetic relay;

FIG. **5** is a sectional view of the polarized electromagnetic relay;

FIG. **6** is an enlarged perspective view depicting a contact section;

FIG. **7** is an exploded perspective view depicting a movable magnetic member and a transmission member;

FIG. **8** is an assembled perspective view depicting the movable magnetic member and transmission member of FIG. **7**;

FIG. **9** is a plan view of the movable magnetic member and transmission member;

FIG. **10** is an enlarged perspective view depicting a portion of the transmission member;

FIG. **11**A is a diagram for explaining the operation of the contact section and the reciprocating movement of the transmission member in a returned state;

FIG. **11**B is a diagram for explaining the operation of the contact section and the reciprocating movement of the transmission member in an operating state;

FIG. **12**A is a diagram for explaining the operation of the movable magnetic member in the returned state;

FIG. **12**B is a diagram for explaining the operation of the movable magnetic member in the operating state;

FIG. **13** is a sectional view that depicts the positions of the contact section and the transmission member when contacts are welded together;

FIG. **14** is a diagram depicting a relationship between a magnetic attractive force and an armature travel;

FIG. **15** is a diagram depicting the relationship between a magnetic attractive force and an armature travel;

FIG. **16**A is a diagram for explaining the operation of a movable magnetic member in a returned state; and

FIG. **16**B is a diagram for explaining the operation of a movable magnetic member in an operating state.

DESCRIPTION OF THE EMBODIMENT

The embodiments of the present invention are described below, in detail, with reference to the accompanying drawings. In the drawings, the same or similar components are denoted by common reference numerals.

FIGS. **1** to **5** depict the configuration of a polarized electromagnetic relay **10** according to one embodiment. FIGS. **6** to **13** depict components of the polarized electromagnetic relay **10**.

The polarized electromagnetic relay **10** includes a base section **12**, an electromagnet **14** supported on the base section **12**, a movable magnetic member **16** moving in accordance with the operation of the electromagnet **14**, a contact section **18** insulated from the electromagnet **14** and supported on the base section **12**, and a transmission member **20** disposed between the electromagnet **14** and the contact section **18** and moving together with the movable magnetic member **16** in accordance with the operation of the electromagnet **14** so as to open and close the contact section **18** (FIGS. **1** to **4**).

The base section **12** includes a first portion **22** supporting the electromagnet **14** and a second portion **24** supporting the contact section **18**. In the plan view of FIG. **3**, the base section **12** has a substantially rectangular profile. The first portion **22** and second portion **24**, each having a substantially rectangular profile, are disposed adjacent each other along the longitudinal direction of the base section **12**. The base section **12** can be integrally formed by, e.g., injection molding from an electrically insulating resin material.

The first portion **22** is provided with a bottom plate **26** on which the electromagnet **14** is mounted. The second portion **24** is provided with an enclosing wall **30** protruding upward relative to the bottom plate **26** of the first portion **22**, and the enclosing wall **30** defines a plurality of accommodation holes **28** respectively accommodating one of a plurality of contact members of the contact section **18**. The enclosing wall **30** provides electrical insulation between the electromagnet **14** and the contact members of the contact section **18**. A bottom face **26***a* of the bottom plate **26** and a bottom face **30***a* of the enclosing wall **30** lie in substantially the same plane, and constitute the entire bottom face of the polarized electromagnetic relay **10** (FIG. **5**).

The enclosing wall **30** includes a peripheral wall portion **30***b* arranged along the profile of the second portion **24**, a center wall portion **30***c* extending in the longitudinal direction of the base section **12**, and a plurality of transverse wall portions **30***d* extending substantially perpendicular to the center wall portion **30***c*. The plurality of accommodation holes **28** are arranged longitudinally in two rows, one on each side of the center wall portion **30***c* and each row having an equal number of accommodation holes, in such a manner as to be symmetrical about the center wall portion **30***c*. In the illustrated example, variously-sized eight recesses extending in a direction substantially perpendicular to the bottom face **30***a* are formed on each side of the center wall portion **30***c* (a total of sixteen recesses on both sides), and six of these recesses (twelve recesses on both sides) serve as the accommodation holes **28** (FIGS. **11**A and **11**B).

The electromagnet **14** includes a bobbin **32**, a coil **34** wound around the bobbin **32**, an iron core **36** received in the bobbin **32**, and a yoke **38** connected to the core **36** and extending outside the coil **34**. The electromagnet **14** is mounted on the bottom plate **26** of the first portion **22** in such a manner that the center axis **34***a* of the coil **34** is oriented along the longitudinal direction of the base section **12** and substantially in parallel to the bottom faces **26***a* and **30***a* of the base section **12** (FIG. **4**).

The bobbin **32** includes a hollow cylindrical body **40** and annular flat plate-like first flange **42** and second flange **44** provided at longitudinally opposite ends of the body **40** (FIG. **5**). The coil **34** is formed by winding a conducting wire around the body **40** of the bobbin **32**, and is held fixedly between the first flange **42** and the second flange **44**. The bobbin **32** can be integrally formed by, e.g., injection molding from an electrically insulating resin material. The bobbin **32** is provided, at the side of the second flange **44**, with two coil terminals **45** respectively connected to the distal ends of the conducting wire forming the coil **34**.

The iron core **36** includes a cylindrical shaft **46** disposed inside the coil **34** along the center axis **34***a* thereof, and a flat plate-like head portion **48** disposed outside the coil **34** and extending radially outward from one axial end of the shaft **46**. The shaft **46** is housed inside the body **40**, and has a length so that the opposite ends of the shaft respectively protrude from the first and second flanges **42** and **44** (FIG. **5**). The head portion **48** is disposed so as to face the first flange **42** with a prescribed gap defined therebetween, and is shaped and dimensioned so that a region **48***a* along the outer periphery of the head portion (hereinafter referred to as a peripheral region **48***a*) slightly protrudes outward from the first flange **42** in the radial direction of the coil. The core **36** can be integrally formed from, e.g., magnetic steel.

The yoke **38** is connected to the axial end **46***a* of the shaft **46** opposite to the head portion **48**, and disposed outside the coil **34** to extend toward the head portion **48** (FIG. **5**). The yoke **38** includes a short and flat plate-like connecting portion **50** connected to the shaft **46** and disposed along the second flange **44**, and a long and flat plate-like major portion **52** disposed substantially orthogonally to the connecting portion **50** at one lateral side of the coil **34** and extending in a direction substantially parallel to the coil center axis **34***a*. The major portion **52** of the yoke **38** is provided with a distal end region **52***a* located at a lateral side of the first flange **42** of the bobbin **32** and spaced apart from the peripheral region **48***a* of the head portion **48** (FIG. **5**). The yoke **38** can be integrally formed as an L-shaped plate from, e.g., magnetic steel. The shaft **46** is fixedly connected to the connecting portion **50** of the yoke **38** by, e.g., crimping. The core **36** cooperates with the yoke **38** to form a magnetic path around the coil **34**.

The electromagnet **14** is supported on the base section **12** while being oriented so that the head portion **48** is located between the coil **34** and the contact section **18**. In other words, as viewed from a side adjacent to the coil terminals **45**, the connecting portion **50** of the yoke **38**, the coil **34**, the head portion **48** of the core **36**, and the contact section **18** are arranged substantially in this order. When the electromagnet **14** is oriented in this manner, it becomes possible to change a relationship between a travel or moving distance of an armature **54** and a magnetic attractive force, compared with a reverse configuration in which the head portion **48** of the core **36** is positioned at a side spaced away from the contact section **18**.

The movable magnetic member **16** includes the armature **54** disposed in the magnetic path of the electromagnet **14** and driven by the electromagnet **14**, and a single permanent magnet **56** attached to the armature **54**. The armature **54** includes a first magnetic pole piece **58** and a second magnetic pole piece **60**, each having a rectangular and flat plate-like shape and formed from a magnetic material such as magnetic steel. The permanent magnet **56** has a rectangular parallelepiped shape, and an N pole and an S pole are formed respectively on the lateral faces **56***a* and **56***b* thereof (FIG. **2**). The first magnetic pole piece **58** and the second magnetic pole piece **60** hold therebetween the permanent magnet **56** in a magnetization direction of the permanent magnet, and are disposed so as to orient the magnetization direction in parallel with the center axis **34***a* of the coil **34** and to face the peripheral region **48***a* (FIG. **5**).

The movable magnetic member **16** including the armature **54** and the permanent magnet **56** is arranged so as to be rectilinearly movable in a reciprocating manner in a direction parallel to the coil center axis **34***a* (a direction indicated by an arrow α in FIG. **5**) in a condition where a part of the first magnetic pole piece **58** is positioned between the peripheral region **48***a* of the head portion **48** and the end region **52***a* of the major portion **52** of the yoke **38**. In other words, the first and second magnetic pole pieces **58** and **60** are rectilinearly movable together with the permanent magnet **56** in an integrated manner in a direction parallel to the coil center axis **34***a*. The reciprocating range or maximum travel of the movable magnetic member **16** is defined by limit positions of movement where the first magnetic pole piece **58** comes into contact respectively with the peripheral region **48***a* of the head portion **48** of the core **36** and the end region **52***a* of the major portion **52** of the yoke **38**.

The first and second magnetic pole pieces **58** and **60** in the present embodiment have respective sizes or dimensions different from each other in a direction perpendicular to the coil center axis **34***a*. In the illustrated configuration, when viewed in a direction perpendicular to the coil center axis **34***a* and the bottom faces **26***a* and **30***a* of the base section **12**, the first magnetic pole piece **58** has a greater dimension than the second magnetic pole piece **60** (FIGS. **2**, **5** and **7**). The other dimensions of the first magnetic pole piece **58** are substantially identical to those of the second magnetic pole piece **60**.

The contact section **18** according to the present embodiment includes four sets of contact members, each set including a first fixed contact member **64** provided with a normally open fixed contact **62** and a first movable contact member **68** having spring properties and provided with a normally open movable contact **66** capable of contacting and separating from the normally open fixed contact **62** (FIG. **6**). Each set of the first fixed contact member **64** and the first movable contact member **68** is referred to as "normally-open contact set **70**".

The contact section **18** further includes two sets of contact members, each set including a second fixed contact member **74** provided with a normally closed fixed contact **72** and a second movable contact member **78** having spring properties and provided with a normally closed movable contact **76** capable of contacting and separating from the normally closed fixed contact **72** (FIG. **6**). Each set of the second movable contact member **78** and the second fixed contact member **74** is referred to as "normally-closed contact set **80**".

In a case where the polarized electromagnetic relay **10** has a monostable configuration, the normally open fixed contact **62** and the normally open movable contact **66** (hereinafter referred to as a pair of normally open contacts) are set in an open or "break" state when the electromagnet **14** is not excited, and are set in a closed or "make" state when the electromagnet **14** is excited. Further, in the monostable configuration, the normally closed fixed contact **72** and the normally closed movable contact **76** (hereinafter referred to as a pair of normally closed contacts) are set in a closed or "make" state when the electromagnet **14** is not excited, and are set in an open or "break" state when the electromagnet **14** is excited.

On the other hand, in a case where the polarized electromagnetic relay **10** has a bistable configuration, even if the electromagnet **14** is turned to be unexcited from a state where the electromagnet **14** is excited and the pair of normally open contacts is closed and the pair of normally closed contacts opens, the closed state of the pair of normally open contacts and the open state of the pair of normally closed contacts are maintained. The selection between the monostable configuration and the bistable configuration can be made by adjusting a relationship between a magnetic force of the electromagnet **14** and permanent magnet **56** and a spring biasing force of the movable contact members **68** and **78**.

The total of twelve contact members of the contact section **18**, including the fixed contact members **64** and **74** and the movable contact members **68** and **78**, are accommodated in the accommodation holes **28**, with two normally-open contact sets **70** and one normally-closed contact set **80** being aligned in the longitudinal direction of the base section **12** at each side of the center wall portion **30***c* (FIG. **3**). Moreover, as viewed from a side adjacent to the first portion **22** of the base section **12**, the second fixed contact member **74**, the second movable contact member **78**, the first movable contact member **68**, the first fixed contact member **64**, the other first movable contact member **68** and the other first fixed contact member **64** are arranged in this order and respectively accommodated in the six accommodation holes **28** formed at each side of the center wall portion **30***c* of the enclosing wall **30** (FIGS. **3**, **11**A and **11**B). The fixed contact members **64** and **74** and the movable contact members **68** and **78** are arranged in symmetrical relationship about the center wall portion **30***c* of the enclosing wall **30**.

Each of the fixed contact members **64** and **74** and the movable contact members **68** and **78** is provided with one longitudinal end region **64***a*, **74***a*, **68***a*, **78***a* (hereinafter referred to as an upper region) protruding upward from a top face **30***e* of the enclosing wall **30** and carrying a contact thereon, and the other longitudinal end region **64***b*, **74***b*, **68***b*, **78***b* (hereinafter referred to as a lower region) protruding downward from the bottom face **30***a* and to be connected to, e.g., a conductor of a not-depicted circuit board (FIG. **11**). The normally open fixed contact **62** and normally open movable contact **66** of each normally-open contact set **70** are disposed above the enclosing wall **30** so as to face each other in the longitudinal direction of the base section **12**. Similarly, the normally closed fixed contact **72** and normally closed movable contact **76** of each normally-closed contact set **80** are disposed above the enclosing wall **30** so as to face each other in the longitudinal direction of the base section **12**.

The normally open movable contact **66** and the normally closed movable contact **76** are configured to be displaced in a rocking manner as the transmission member **20** moves in response to the rectilinear movement of the movable magnetic member **16**. The normally open movable contact **66** and the normally closed movable contact **76** alternatively contacts with and separated from the normally open fixed contact **62** and the normally closed fixed contact **72**, respectively, facing in a rocking direction, so that one contact pair is closed when the other contact pair is opened. Each of the first and second movable contact members **68** and **78** is configured so that at least the portion thereof including the upper region **68***a*, **78***a* is formed by punching a material having spring properties, such as a thin plate of phosphor bronze used for making a spring, and elastically deflects while generating a required spring biasing force, in response to a force applied by the transmission member **20**. On the other hand, each of the first and second fixed contact members **64** and **74** is formed as a whole by punching a plate of phosphor bronze used for making a spring of other electrically conductive metal, and has rigidity such that it does not substantially deflect (or only slightly deflects) when subjected to a force applied by the counterpart first or second movable contact member **68**, **78** at a time of closing the contacts.

The transmission member **20** includes a first portion **82** supporting the movable magnetic member **16** and a second portion **84** engaging with the first and second movable contact members **68** and **78** (FIGS. **1** and **3**). In the plan view of FIG. **3**, the transmission member **20** has a substantially rectangular profile smaller than that of the base section **12**, and the first portion **82** and the second portion **84** are disposed adjacent each other in the longitudinal direction of the transmission member **20**. The transmission member **20** can be integrally formed by, e.g., injection molding from an electrically insulating resin material.

The transmission member **20** is mounted on the enclosing wall **30** so as to face the top face **30***e* thereof, in a state where its longitudinal sides are oriented in parallel to the center axis **34***a* of the coil **34** and the first portion **82** is positioned at a side adjacent to the electromagnet **14** (FIG. **1**). In this state, the transmission member **20** can reciprocate in a sliding fashion relative to the base section **12**. As will be described later, the transmission member **20** transmits the movement of the armature **54** to the first and second movable contact members **68** and **78** of the contact section **18**, and opens and closes the normally open movable contact **66** and normally closed movable contact **76**.

The first portion **82** of the transmission member **20** is provided with a hollow space **86** for accommodating the movable magnetic member **16** therein (FIG. **7**). The first and second magnetic pole pieces **58** and **60** of the armature **54** and the permanent magnet **56** held between the magnetic pole pieces **58** and **60** are fixed inside the hollow space **86** by, e.g., press fitting or adhesion, with the magnetization direction of the permanent magnet **56** oriented in the longitudinal direction (i.e., in the moving direction) of the transmission member **20** (FIG. **8**). When the transmission member **20** is mounted on the enclosing wall **30** of the base section **12**, the armature **54** and permanent magnet **56** supported on the first portion **82** and the electromagnet **14** supported on the first portion **22** of the base section **12** are properly positioned in the aforementioned relative arrangement (FIG. **5**). The second portion **84** of the transmission member **20** transmits the movement of the transmission member **20** to the first and second movable contact members **68** and **78** supported on the second portion **24** of the base section **12**.

The second portion **84** of the transmission member **20** is provided with four first hollow spaces **88** for respectively accommodating the upper regions **68***a* of the first movable contact members **68** and two second hollow spaces **90** for respectively accommodating the upper regions **78***a* of the second movable contact members **78**. The first and second hollow spaces **88** and **90** being arranged correspondingly to the arrangement of the first and second movable contact members **68** and **78** on the base section **12** (FIG. **1**). Each first hollow space **88** is provided with a pair of first projecting pieces **92** (FIGS. **7** and **8**) engagable respectively with the opposite lateral edges of the upper region **68***a* of the first movable contact member **68**. The first projecting pieces **92** being opposed to and spaced from each other in the lateral or transverse direction of the transmission member **20**. Similarly, each second hollow space **90** is provided with a pair of second projecting pieces **94** (FIGS. **7** and **8**) engagable respectively with the opposite lateral edges of the upper region **78***a* of the second movable contact member **78**. The second projecting pieces **94** being opposed to and spaced from each other in the lateral or transverse direction of the transmission member **20**. Each first hollow space **88** is further provided with a slit **96** (FIGS. **7** and **8**), formed adjacent to the first projecting piece **92** at the side of the outer edge of the transmission member **20**, for receiving one lateral edge of the upper region **68***a* of the first movable contact member **68**.

The first hollow space **88** located farthest from the first portion **82** in the second portion **84** (at a rightmost end in FIGS. **1** and **3**) (hereinafter referred to as a rightmost first hollow space **88***a*) is formed so that the pair of first projecting pieces **92** provides an end face of the transmission member **20**. The normally open movable contact **66** of the first movable contact member **68** with the upper region **68***a* thereof being accommodated in the rightmost first hollow space **88***a* is disposed so as to protrude outward from the transmission member **20** through the gap between the first projecting pieces **92** and face the normally open fixed contact **62** of the first fixed contact member **64** of the same normally-open contact set **70**. The first hollow space **88** located in the middle of the second portion **84** (hereinafter referred to as a middle first hollow space **88***b*) communicates with a third hollow space **98** formed on the opposite side of the pair of first projecting pieces **92** nearer to the rightmost first hollow space **88***a* through the gap between the first projecting pieces **92** (FIGS. **1** and **3**). The upper region **64***a* of the first fixed contact member **64** is accommodated in the third hollow space **98**. The normally open movable contact **66** of the first movable contact member **68** with the upper region **68***a* thereof being accommodated in the middle first hollow space **88***b* is disposed so as to protrude into the third hollow space **98** through the gap between the first projecting pieces **92** and face the normally open fixed contact **62** accommodated in the third hollow space **98**.

The second hollow space **90** communicates with a fourth hollow space **100** formed on the side of the pair of second projecting pieces **94** nearer to the hollow space **86** through the gap between the second projecting pieces **94** (FIGS. **1** and **3**). The upper region **74***a* of the second fixed contact member **74** is accommodated in the fourth hollow space **100**.

The normally closed movable contact **76** of the second movable contact member **78** with the upper region **78***a* thereof being accommodated in the second hollow space **90** is disposed so as to protrude into the fourth hollow space **100** through the gap between the second projecting pieces **94** and face the normally closed fixed contact **72** accommodated in the fourth hollow space **100**. The base section **12** is provided on the top face **30***e* with an upright wall **102** projecting therefrom for supporting the normally closed fixed contact **72** accommodated in the fourth hollow space **100** at a position adjacent to the first portion **22**. The wall **102** is also accommodated in the fourth hollow space **100** of the transmission member **20** (FIGS. **1** and **3**).

The transmission member **20** is provided with a total of four pawls **104**, two pawls being dispersedly arranged on each side of the coil center axis **34***a*, each of which slidably engages with the base section **12** (only pawls on one side is depicted in FIG. **1**). The pawls **104** extend in one direction (downward in the drawing) from the respective side walls of the transmission member **20** at positions symmetrical about the coil center axis **34***a*. As depicted in FIGS. **9** and **10**, each pawl **104** is provided with a hook **106** formed to protrude toward the inside of the transmission member **20**. The base section **12** is provided with a pair of guide rails **108** for guiding the four pawls **104** in a direction parallel to the coil center axis **34***a*, adjacent to the top face **30***e* of the enclosing wall **30** (FIGS. **1**, **3** and **10**). The guide rails **108** extend linearly along the longitudinal direction of the base section **12** at positions symmetrical about the coil center axis **34***a*. Each guide rail **108** receives the hooks **106** in a slidable fashion.

As the four pawls **104** formed on both side walls of the transmission member **20** engage with the pair of guide rails **108**, the transmission member **20** is held on the base section **12** so as to be prevented from falling off, and the transmission member **20** is enabled to reciprocate in a stable manner on the base section **12**. The stability of the reciprocating movement of the transmission member **20** may be further enhanced by providing more than two pawls **104** on each side, i.e., total of more than four pawls **104**, symmetrically about the coil center axis **34***a*.

The polarized electromagnetic relay **10** further includes a casing (not depicted) that contains the electromagnet **14**, the movable magnetic member **16**, the contact section **18** and the transmission member **20**. The casing has a substantially rectangular parallelepiped profile, and an opening for inserting therethrough the electromagnet **14**, the movable magnetic member **16**, the contact section **18** and the transmission member **20** to the interior of the casing is formed in its one side. The casing can be fixed to the base section **12** by an adhesive. The casing can be integrally formed from an electrically insulating resin material.

An exemplary operation of the polarized electromagnetic relay **10** will be described below. The following description is given for an embodiment wherein the polarized electromagnetic relay **10** has a monostable configuration. In the following description, a state where the pair of normally open contacts of the contact section **18** is closed and the pair of normally closed contacts thereof is opened is referred to as an "operating state", and a state where the pair of normally open contacts of the contact section **18** is opened and the pair of normally closed contacts thereof is closed is referred to as a "returned state".

FIG. **11**A depicts the positions of the contact section **18** and the transmission member **20** when the polarized electromagnetic relay **10** is in the returned state. FIG. **11**B depicts the positions of the contact section **18** and the transmission member **20** when the polarized electromagnetic relay **10** is in the operating state. FIG. **12**A depicts the position of the movable magnetic member **16** when the polarized electromagnetic relay **10** is in the returned state. FIG. **12**B depicts the position of the movable magnetic member **16** when the polarized electromagnetic relay **10** is in the operating state. FIG. **13** depicts the positions of the contact section **18** and the transmission member **20** when one of contact pairs in the contact section **18** is welded.

In the returned state of the polarized electromagnetic relay **10**, the contact section **18** is in a condition where each normally closed fixed contact **72** and normally closed movable contact **76** are closed, while each normally open fixed contact **62** and normally open movable contact **66** are opened (FIG. **11**A). In this condition, the electromagnet **14** is in an unexcited state, and the movable magnetic member **16** is located at a returned position where the first magnetic pole piece **58** is spaced from the peripheral region **48***a* of the head portion **48** of the core **36** while contacting the end region **52***a* of the major portion **52** of the yoke **38** (FIG. **12**A). The transmission member **20** is located at a first limit position of movement closest to the electromagnet **14** (a leftmost position in the drawing) (FIG. **1**, FIGS. **3** to **5**).

In the returned state, the transmission member **20** does not apply a force for deflection to the respective first and second movable contact members **68** and **78**. When the force is not applied by the transmission member **20**, the first movable contact member **68** is not deflected, and thus the normally open movable contact **66** is separated from the counterpart normally open fixed contact **62** (this configuration will hereinafter be referred to as an "initial configuration" of the first movable contact member **68**). Also, when the force is not applied by the transmission member **20**, the second movable contact member **78** is slightly deflected and the normally closed movable contact **76** contacts the counterpart normally closed fixed contact **72**, and thus the normally closed movable contact **76** is pressed against the normally closed fixed contact **72** by the action of a spring biasing force (this configuration will hereinafter be referred to as an "initial configuration" of the second movable contact member **78**). With the respective first and second movable contact members **68** and **78** maintaining their initial configurations, the contact section **18** is retained at a normally-closed contact "make" position where the normally open movable contact **66** is separated from the normally open fixed contact **62** while the normally closed movable contact **76** contacts the normally closed fixed contact **72** in an electrically-conductive manner (FIG. **11**A). In the returned state, a slight amount of magnetic attractive force due to the permanent magnet **56** acts between the first magnetic pole piece **58** and the major portion **52** of the yoke **38**.

When the electromagnet **14** is excited in the returned state, magnetic force generated by the electromagnet **14** and the permanent magnet **56** causes the movable magnetic member **16** to move to an operating position where the first magnetic pole piece **58** is spaced from the end region **52***a* of the major portion **52** of the yoke **38** while contacting the peripheral region **48***a* of the head portion **48** of the core **36** (FIG. **12**B). The direction of a magnetic flux produced by the excitation of the electromagnet **14** is oriented, with respect to the direction of a magnetic flux produced by the permanent magnet **56**, in such a manner that a repulsion force is produced between the first magnetic pole piece **58** and the major portion **52** of the yoke **38** while an attraction force is produced between the first magnetic pole piece **58** and the head portion **48** of the core **36**. During the movement of the movable magnetic member **16** from the returned position to the operating position, the transmission member **20** moves together with the movable magnetic member **16** in the direction parallel to the coil center axis **34***a* while the pawls **104** are guided along the guide rails **108** of the base section **14** as the movable magnetic member **16** moves. The rectilinear movement of the transmission member **20** is transmitted via the first projecting pieces **92**, slits **96** and second projecting pieces **94** of the transmission member **20** to the upper regions **68***a* and **78***a* of the first and second movable contact members **68** and **78**, and the upper regions **68***a*, **78***a* of the movable contact members **68**, **78** elastically deflect while increasing the spring biasing force thereof.

Consequently, at the instant when the magnetic force generated by the excitation of the electromagnet **14** in a direction for bringing the first magnetic pole piece **58** into contact with the peripheral region **48***a* of the head portion **48** of the core **36** exceeds the total amount of force required to cause the upper regions **68***a*, **78***a* of the movable contact members **68**, **78** to deflect from the initial configurations thereof, the movable magnetic member **16** starts to move from the returned position toward the operating position, and the transmission member **20** starts to move accordingly.

When the movable magnetic member **16** reaches the operating position, the transmission member **20** is located at a second limit position of movement farthest away from the electromagnet **14** (a rightmost position in the drawing) (FIG. **11**B). At this moment, the contact section **18** is in a condition where the normally closed fixed contact **72** and normally closed movable contact **76** in each normally-closed contact set **80** are opened, while the normally open fixed contact **62** and normally open movable contact **66** in each normally-open contact set **70** are closed (FIG. **11**B). Thus, the polarized electromagnetic relay **10** is set in the operating state.

When the polarized electromagnetic relay **10** is shifted from the returned state to the operating state, a magnetic attractive force generated due to the electromagnet **14** and the permanent magnet **56** acts between the first magnetic pole piece **58** and the head portion **48** of the core **36**. As a result, the contact section **18** is retained at a normally-open contact "make" position where the normally closed movable contact **76** is separated from the normally closed fixed contact **72** while the normally open movable contact **66** contacts the normally open fixed contact **62** in an electrically-conductive manner against the spring biasing force of the movable contact members **68**, **78** (FIG. **11**B).

When the excitation of the electromagnet **14** is halted in the operating state by shutting off an electric current flowing through the coil **34**, the spring biasing forces of the respective movable contact members **68** and **78** are applied from the respective upper regions **68***a* and **78***a* to the first projecting pieces **92**, slits **96** and second projecting pieces **94**, which causes the movable magnetic member **16** to move to the returned position where the first magnetic pole piece **58** is separated from the peripheral region **48***a* while contacting the end region **52***a* (FIG. **12**A). During the movement of the movable magnetic member **16** from the operating position to the returned position, the transmission member **20** moves together with the movable magnetic member **16** in the direction parallel to the coil center axis **34***a* while the pawls **104** are guided along the guide rails **108** of the base section **14**.

When the movable magnetic member **16** reaches the returned position, the transmission member **20** is located at the first limit position of movement (FIG. **11**A). At this moment, the contact section **18** is in a condition where the normally closed fixed contact **72** and normally closed movable contact **76** in each normally-closed contact set **80** are closed, while the normally open fixed contact **62** and normally open movable contact **66** in each normally-open contact set **70** are opened (FIG. **11**A). Thus, the polarized electromagnetic relay **10** is set in the returned state.

In an embodiment wherein the polarized electromagnetic relay **10** has a bistable configuration, even if the excitation of the electromagnet **14** is halted in the operating state depicted in FIGS. **11**B and **12**B, the movable magnetic member **16** is retained at the operating position by the action of the permanent magnet **56**, and the contact section **18** is retained at a normally-open contact "make" position. In this state, if the electromagnet **14** is excited in a reverse direction by, e.g., applying electric current through the coil in a direction opposite to the direction of the current applied to shift the relay from the returned state to the operating state, the movable magnetic member **16** moves to the returned position of FIG. **12**A due to the magnetic force generated by the electromagnet **14** and the permanent magnet **56**.

The direction of a magnetic flux produced at this moment by the electromagnet **14** is oriented, with respect to the direction of a magnetic flux produced by the permanent magnet **56**, in such a manner that a repulsion force is produced between the first magnetic pole piece **58** and the head portion **48** of the core **36** while an attraction force is produced between the first magnetic pole piece **58** and the major portion **52** of the yoke **38**. During the movement of the movable magnetic member **16** from the operating position to the returned position, the upper regions **68***a* and **78***a* of the first and second movable contact members **68** and **78** tend to be elastically restored to their original configurations.

Consequently, at the instant when the sum of the magnetic force generated by the reverse excitation of the electromagnet **14** in a direction for bringing the first magnetic pole piece **58** into contact with the end region **52***a* of the major portion **52** of the yoke **38** and the elastic restoring forces generated by the movable contact members **68**, **78** exceeds the magnetic force generated by the permanent magnet **56** to retain the movable magnetic member **16** at the operating position, the movable magnetic member **16** starts to move from the operating position toward the returned position, and the transmission member **20** starts to move accordingly.

In the returned state, a magnetic attractive force due to the electromagnet **14** and the permanent magnet **56** acts between the first magnetic pole piece **58** and the major portion **52** of the yoke **38**. As a result, the contact section **18** is retained at a normally-closed contact "make" position where the normally open movable contact **66** is separated from the normally open fixed contact **62** while the normally closed movable contact **76** contacts the normally closed fixed contact **72** in an electrically-conductive manner (FIG. **11**A).

As described above, in accordance with the rectilinear movement of the armature **54** (or the movable magnetic member **16**) in the direction parallel to the coil center axis **34***a*, the transmission member **20** rectilinearly moves in the direction parallel to the coil center axis **34***a*, and opens and closes the normally open movable contacts **66** and the normally closed movable contacts **76** in a mechanically mutually interlocked manner. According to the above-described transmission member **20**, the polarized electromagnetic relay **10** can be used as a so-called safety relay in which, if the pair of normally open contacts is welded together during the operating state of the relay, it is possible to prevent the pair of normally closed contacts from closing even when the relay is set back to the returned state. A circuit incorporating such a safety relay can detect the welding of the pair of normally open contacts and can maintain a power shutoff condition.

Assuming the case where the normally open fixed contact **62** and normally open movable contact **66** of any one of the four normally-open contact sets **70** are fused together in the operating state of FIG. **11**B. If the electromagnet **14** is turned to an unexcited condition in the operating state, the transmission member **20** starts moving toward the returned position. However, the movement of the transmission member **20** stops at the position depicted in FIG. **13**, as the upper region **68***a* of the first movable contact member **68** is engaged with the first projecting pieces **92** and the slit **96** of the transmission member **20**, and the welded normally-open contact set **70** prevents the transmission member **20** from moving further. Accordingly, even if any of the normally open contact set is welded, the transmission member **20** is retained at a middle position between the first and second limit positions of movement, as depicted in FIG. **13**.

When the transmission member **20** is located at the middle position, each of the remaining three normally-open contact sets **70** is set in a contact open state with the normally open fixed contact **62** separated from the normally open movable contact **66**, and each of the two normally closed contact sets **80** is also set in a contact open state with a prescribed gap ensured between the normally closed fixed contact **72** and the normally closed movable contact **76**.

In the polarized electromagnetic relay **10** of the embodiment, if any normally closed contact set **80** does not close while the transmission member **20** has to be positioned in the returned position, it is possible to detect an abnormal operation of the contact section **18** by detecting the non-closed condition of the normally-closed contact set **80**, by using a circuit incorporated in the polarized electromagnetic relay **10**. Thus, it is possible to detect the welding of the pair of normally open contacts in any of the normally-open contact sets **70** as a possible cause for the abnormal operation of the contact section **18**. Note that such an application of the polarized electromagnetic relay **10** as a safety relay can be implemented as long as the polarized electromagnetic relay **10** includes at least one normally-open contact set **70** and at least one normally-closed contact set **80**. As the number of normally-open contact sets **70** and normally-closed contact sets **80** increases, the safety and reliability of the safety relay can be improved.

In the polarized electromagnetic relay **10** of the embodiment, the electromagnet **14** is mounted with the center axis **34***a* of the coil **34** oriented in parallel to the bottom faces **26***a*, **30***a* of the base section **12**, and is designed to move the movable magnetic member **16** rectilinearly in the direction parallel to the center axis **34***a* of the coil **34**. Therefore, it is possible to effectively reduce the entire outer dimensions of the relay **10** defined in the radial direction of the coil. Furthermore, the first and second magnetic pole pieces **58** and **60** are designed to hold therebetween the permanent magnet **56** in the magnetization direction thereof and to orient the magnetization direction in parallel to the coil center axis **34***a*, and therefore, the movable magnetic member **16** can be simplified and downsized. Further, the armature **54** is fixedly connected to the transmission member **20** with the first and second magnetic pole pieces **58**, **60** holding the permanent magnet **56** therebetween, and therefore, it is possible to effectively transmit the moving action of the armature **54** to the contact section **18** by the transmission member **20**.

As described above, the polarized electromagnetic relay **10** includes two or more contact pairs, i.e., four or more contact members that can be used to implement a safety relay. Further, the moving direction of the movable magnetic member **16**, the magnetization direction of the permanent magnet **56**, and the moving direction of the transmission member **20** are all aligned in parallel to the coil center axis **34***a*. Therefore, the polarized electromagnetic relay **10** can be easily downsized, especially decreased in height, and can reduce power consumption due to a polarized configuration.

In the above-described polarized electromagnetic relay **10**, the magnetic pole pieces **58**, **60** of the armature **54** have respective sizes different from each other in a direction substantially perpendicular to the coil center axis **34***a*. Magnetic force acting on the armature **54** during the excitation of the electromagnet **14** varies depending on the size of the surface of each magnetic pole piece **58**, **60** forming a pole face of the armature **54** to which the permanent magnet **56** is attached. Accordingly, when the magnetic pole pieces **58**, **60** have different sizes, magnetic force acting on a larger magnetic pole piece is greater than magnetic force acting on a smaller magnetic pole piece.

In the illustrated configuration, the first magnetic pole piece **58** that alternately contacts the peripheral region **48***a* of the head portion **48** of the core **36** and the end region **52***a* of the major portion **52** of the yoke **38** is larger than the second magnetic pole piece **60**. Therefore, it is possible to increase a magnetic force acting on the armature **54** when the electromagnet **14** is excited, in comparison with a configuration wherein the first magnetic pole piece **58** has the same size as the second magnetic pole piece **60**.

FIG. **14** depicts a relationship between a magnetic attractive force and a travel or moving distance of the armature **54** in a configuration in which the first magnetic pole piece **58** has a size larger than the second magnetic pole piece **60** (example 1), in comparison with a configuration in which the first magnetic pole piece **58** has a size identical to the second magnetic pole piece **60** (example 2). In FIG. **14**, a horizontal axis represents travel, or moving distance, of the armature **54** from the position where the first magnetic pole piece **58** contacts the peripheral region **48***a* (FIG. **12**B) when the first magnetic pole piece **58** moves toward the end region **52***a*. A vertical axis represents a magnetic attractive force generated by the electromagnet **14** and the permanent magnet **56** to attract the first magnetic pole piece **58** toward the peripheral region **48***a* of the head portion **48**. A positive magnetic attractive force is a force for attracting the first magnetic pole piece **58** toward the head portion **48** of the core **36**, and a negative magnetic attractive force is a force for repulsing the first magnetic pole piece **58** away from the head portion **48** of the core **36**.

In FIG. **14**, solid line L**1** represents a relationship between the travel of the armature and the magnetic attractive force at a certain pick-up (or operate) ampere in example 1. Solid line L**2** represents a relationship between the travel of the armature and the magnetic attractive force at a drop-out (or release) ampere (i.e., zero ampere) in example 1. Dashed line L**3** represents a relationship between the travel of the armature and the magnetic attractive force at a certain pick-up (or operate) ampere in example 2. Dashed line L**4** represents a relationship between the travel and the magnetic attractive force at a drop-out (or release) ampere (i.e., zero ampere) in example 2. As depicted, in example 1, compared with example 2, the magnetic attractive force is increased over the entire travel of the armature **54**. The increase in the magnetic attractive force can make the magnetic attractive force correspond to the magnitude of the spring biasing force applied to the armature **54** from the movable contact members **68**, **78** via the transmission member **20**, and thus can optimize the operating characteristics of the polarized electromagnetic relay **10**. Accordingly, when the size of the first magnetic pole piece **58** is adjusted in the direction perpendicular to the coil center axis **34***a*, it is possible to adjust the operating characteristics of the polarized electromagnetic relay **10** so as to correspond to the magnitude of the spring biasing force.

In the above-described polarized electromagnetic relay **10**, the electromagnet **14** is oriented so that the head portion **48** of the core **36** is located between the coil **34** and the contact section **18**. When the electromagnet **14** is oriented in this manner, it is possible to change a relationship between a magnetic attractive force and a travel of the armature **54** as described below, compared with a reverse configuration in which the head portion **48** of the core **36** is located at a side spaced away from the contact section **18**. In this connection, it is presumed that, when the orientation of the electromagnet **14** relative to the contact section **18** is reversed, the relationship between the magnetic force generated due to the electromagnet **14** and the permanent magnet **56** and the spring biasing force of the movable contact members **68**, **78** changes, and the relationship between the magnetic attractive force and the travel of the armature **54** changes.

FIG. **15** depicts a relationship between a magnetic attractive force and a travel of the armature **54** in a configuration in which the head portion **48** of the core **36** is located between the coil **34** and the contact section **18** (example 3) in comparison with a reverse configuration (example 4). In FIG. **15**, a horizontal axis and a vertical axis represent the travel of the armature and the magnetic attractive force, respectively, in the same manner as in FIG. **14**. In FIG. **15**, solid line L**5** represents a relationship between the travel and the magnetic attractive force at a certain pick-up (or operate) ampere in example 3. Solid line L**6** represents a relationship between the travel and the magnetic attractive force at a drop-out (or release) ampere (i.e., zero ampere) in example 3. Dashed line L**7** represents a relationship between the travel and the magnetic attractive force at a pick-up (or operate) ampere in example 4. Dashed line L**8** represents a relationship between the travel and the magnetic attractive force at a drop-out (or release) ampere (i.e., zero ampere) in example 4. As depicted in FIG. **15**, in example 3, compared with example 4, the rate of change in the magnetic attractive force is reduced, especially when a travel of the armature **54** is relatively small. The reduction in the rate of change in the magnetic attractive force can approximate the rate of change in the magnetic attractive force to the rate of change in the magnitude of the spring biasing force applied to the armature **54** from the movable contact members **68**, **78** via the transmission member **20**, and thus can optimize the operating characteristics of the polarized electromagnetic relay **10**. Accordingly, when either example 3 or 4 is selected as the orientation of the electromagnet **14** relative to the contact section **18**, it is possible to appropriately change the operating characteristics of the polarized electromagnetic relay **10** so as to correspond to the rate of change in the magnitude of the spring biasing force.

In the above-described polarized electromagnetic relay **10**, the first magnetic pole piece **58** is spaced from the peripheral region **48***a* and contacts the end region **52***a*, and the second magnetic pole piece **60** is spaced from the peripheral region **48***a* in the returned state of the relay, as depicted in FIG. **12**A. In other words, in the returned state, a clearance is defined between both of the first and second magnetic pole pieces **58**, **60** and the peripheral region **48***a*. The clearance defined between the second magnetic pole piece **60** and the head portion **48** of the core **36** in the returned state is, e.g., about 0.2 mm. The size of the clearance can be appropriately set by selecting the dimension of the permanent magnet **56** in a direction parallel to the coil center axis **34***a* or a minimum distance between the peripheral region **48***a* and the end region **52***a*.

In the configuration where the armature **54** operates so that a clearance is defined between the first and second magnetic pole pieces **58**, **60** and the peripheral region **48***a* in the returned state, it is possible to reduce the rate of change in the magnetic attractive force, especially in a range of a less travel of the armature **54**, in the same manner as in example 3 depicted in FIG. **15**, compared with a configuration in which the first magnetic pole piece **58** contacts the end region **52***a* and simultaneously the second magnetic pole piece **60** contacts the peripheral region **48***a* in the returned state. Further, it is possible to adjust the rate of change in the magnetic attractive force in accordance with the size of the above clearance. In this connection, it is presumed that, when the clearance is provided or not provided, or when the size of the above clearance is changed, the relationship between the magnetic force generated by the electromagnet **14** and the permanent magnet **56** and the spring biasing force of the movable contact members **68**, **78** changes, and the relationship between the magnetic attractive force and the travel of the armature **54** changes.

FIG. **16** depicts a modification of the polarized electromagnetic relay **10**. In the modification of FIG. **16**, the first magnetic pole piece **58'** of the armature **54'** is spaced from both of the peripheral region **48***a***'** and the end region **52***a***'**, while the second magnetic pole piece **60'** of the armature **54'** contacts the peripheral region **48***a***'** in the returned state of the relay (FIG. **16**A). On the other hand, in the operating state of the relay, the first magnetic pole piece **58'** is spaced from the end region **52***a***'** and contacts the peripheral region **48***a***'**, while the second magnetic pole piece **60'** is spaced from the peripheral region **48***a***'** (FIG. **16**B). In other words, in the returned state, a clearance is defined between the first magnetic pole piece **58'** and both of the head portion **48'** of the core **36'** and the end region **52***a***'** of the yoke **38'**. The clearance defined between the first magnetic pole piece **58'** and the end region **52***a***'** of the yoke **38'** in the returned state is, e.g., about 0.2 mm. The size of the clearance can be appropriately set by selecting the dimension of the permanent magnet **56'** in a direction parallel to the coil center axis **34***a***'** or a minimum distance between the peripheral region **48***a***'** of the head portion **48'** of the core **36'** and the end region **52***a***'** of the major portion **52'** of the yoke **38'**.

In the configuration where the armature **54'** operates so that a clearance is defined between the first magnetic pole piece **58'** and both of the head portion **48'** of the core **36'** and the end region **52***a***'** of the yoke **38'** in the returned state, it is possible to reduce the rate of change in the magnetic attractive force, especially in a range of a less travel of the armature **54'**, in the same manner as in example 3 depicted in FIG. **15**, compared with a configuration in which the second magnetic pole piece **60'** contacts the peripheral region **48***a***'** and simultaneously the first magnetic pole piece **58'** contacts the end region **52***a***'** in the returned state. Further, it is possible to adjust the rate of change in the magnetic attractive force in accordance with the size of the above clearance. Note that the modification depicted in FIG. **16** is configured so that the first and second magnetic pole pieces **58'** and **60'** have a mutually identical size.

While the invention has been described with reference to specific embodiments, it will be understood by those skilled in the art that various changes and modifications may be made thereto without departing from the scope of the following claims.

The invention claimed is:

1. An electromagnetic relay, comprising:

an electromagnet that includes a coil wrapped around a shaft disposed along a center axis of the coil and having first and second axial ends;

a first contact that includes first contact members respectively supporting a first fixed contact and a first movable contact that contacts with and is separated from the first fixed contact;

a second contact that includes second contact members, separately formed from the first contact members, respectively supporting a second fixed contact and a second movable contact that contacts with and is separated from the second fixed contact;

a transmission member that is movable in a direction along the center axis of the coil, and simultaneously actuates the first movable contact and the second movable contact so as to alternatively open and close the first contact and the second contact; and

a first magnetic pole piece attached to the transmission member, and is actuated in response to excitation of the electromagnet;

a second magnetic pole piece attached to the transmission member to align with the first magnetic pole piece in the direction along the center axis, and actuated together with the first magnetic pole piece; and

a permanent magnet attached between the first and second magnetic pole pieces, having a magnetization direction of the permanent magnet parallel to the center axis;

wherein the transmission member moves in response to the actuation of the first and second magnetic pole pieces;

wherein the electromagnet further includes

a head portion, located between the coil and the first and second contacts and positioned between the first and second magnetic pole pieces, radially extending outward from the first axial end of the shaft to outside the coil; and

a yoke connected at a first end to the second axial end of the shaft and extending outside the coil toward the head portion at a second end; and

wherein one of the first and second magnetic pole pieces is located between the head portion and the second end of the yoke.

2. The electromagnetic relay of claim 1, wherein said first and second magnetic pole pieces have respective sizes different from each other.

3. The electromagnetic relay of claim 2, wherein one of the magnetic pole pieces, located between the coil and the head portion, is larger than the other of the magnetic pole pieces.

4. The electromagnetic relay of claim 1, wherein a clearance is defined between one of said first and second magnetic pole pieces and said head portion when the transmission member is in a returned state.

5. The electromagnetic relay of claim 1,

further comprising a base section that supports said first and second contacts,

wherein said transmission member includes a pawl that slidably engages with said base section; and

wherein said base section includes a guide rail that guides said pawl along said direction parallel to said center axis.

6. The electromagnetic relay of claim 1, wherein the first contact is a normally-open contact and the second contact is a normally-closed contact, and wherein said transmission member operates to ensure a gap between said second fixed contact and said second movable contact when the first fixed contact is welded to the first movable contact.

7. An electromagnetic relay, comprising:

an electromagnet that includes a coil;

a base;

a first contact that includes a first fixed contact member having one end fixed to the base and another end on which a first fixed contact is provided, a first movable contact member having one end fixed to the base and another end on which a first movable contact is provided, wherein the first contact is a normally-open contact, and the first movable contact contacts with and is separated from the first fixed contact;

a second contact, physically separated from the first contact, that includes a second fixed contact member having one end fixed to the base and another end on which a second fixed contact is provided, a second movable contact member having one end fixed to the base and another end on which a second movable contact is provided, wherein the second contact is a normally-closed contact, and the second movable contact contacts with and is separated from the second fixed contact; and

a transmission member that is movable in a direction along a center axis of the coil, and simultaneously actuates the first movable contact member and the second movable contact member so as to alternatively open and close the first contact and the second contact, the transmission member having a slit that receives one of opposite lateral edges of the other end of the first movable contact member, on which the first movable contact is provided, and a pair of projecting pieces engageable respectively with the opposite lateral edges.

8. The electromagnetic relay of claim 7, wherein said transmission member operates to ensure a gap between said second fixed contact and said second movable contact when the first fixed contact is welded to the first movable contact.

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